TMDLs FOR DISSOLVED OXYGEN FOR THE CALCASIEU ESTUARY

SUBSEGMENTS 030305, 030801, 030806, 030901, and 031001

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Executive Summary

Section 303(d) of the Clean Water Act requires the identification, listing, ranking, and development of Total Maximum Daily Loads (TMDLs) for waters that do not meet applicable water quality standards after the implementation of technology-based controls. The State of Louisiana's current Section 303(d) list of impaired waterbodies was released on October 28, 1999 by the U.S. Environmental Protection Agency (USEPA) Region 6. This list was developed by the USEPA as a result of a Court Order against the USEPA Region 6 on October 1, 1999. Included on the list are Contraband Bayou (Subsegment 030305), Bayou D'Inde (Subsegment 030901), and West Fork of Calcasieu River (West Fork) (Subsegment 030801). These tributaries to the Calcasieu River, as well as other tributaries listed on the State of Louisiana's 2000 Section 305(b) list of waterbodies not fully supporting one or more uses, were targeted for the development of TMDLs for oxygen. Subsegments listed on the 2000 Section 305(b) list include 031001 (Bayou Choupique) and a 3.8-kilometer (km) portion of 030806 (Houston River). Contraband Bayou and Bayou D'Inde were also listed on the court-ordered list for nutrients. LDEQ's position, as supported by the declaratory ruling issued by Secretary Givens in response to the lawsuit regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited.

In 1985, a calibrated model was developed for the Calcasieu River Basin and wasteload allocations for Bayou D'Inde and portions of Contraband Bayou, West Fork, and Bayou Choupique were developed and approved by the USEPA. However, updating and expansion of the model was necessary as part of the current study to cover upstream portions of the West Fork, Contraband Bayou, Bayou Choupique, and approximately 3.8 km of the Houston River and to account for changes in point source loadings in these watersheds. The model expansions are described below:

- Subsegment 030305 – Contraband Bayou (Estuarine) – From river kilometer (RK) 3.04 to RK 9.89;
- Subsegment 030801 – West Fork – From RK 8.23 to RK 26.27;
- Subsegment 030806 – Houston River – From RK 0.0 to RK 3.81; and

- Subsegment 031001 – Bayou Choupique – From RK 12.95 to RK 31.80 Headwaters to Intracoastal Waterway (Estuarine).

For the purposes of the study, West Fork and the Houston River were combined into one model segment. The combined model segment was referred to as "West Fork/Houston River".

An extensive file search was conducted to locate and update known oxygen-demanding point source discharges within the areas covered by the 1985 TMDL study and the new model expansion areas. The file review included the collection of data from National Pollutant Discharge Elimination System/Louisiana Pollutant Discharge Elimination System (NPDES/LPDES) files, permit applications, and inspection reports. The resulting list of dischargers was designated as the 2001 discharger inventory. In addition, a field survey was conducted on June 26 and 27, 2001 by Louisiana Department of Environmental Quality (LDEQ) for the purpose of obtaining measured data against which simulated concentrations could be calibrated for the expanded portions of the model network. Ambient and historical data were also collected for the development of the calibration and seasonal projection models.

Calibration of the expanded portions of the model was accomplished through the simulation of hydrodynamic and water quality parameters within the range of measured data from the 2001 field survey. Seasonal projection models were developed for each subsegment in this study by incorporating those portions of each subsegment that were originally included in the 1985 model with the expanded portions of the calibrated model that were completed as part of this study. Critical flows and background stream temperatures were applied in accordance with the 2001 LDEQ TMDL Louisiana Technical Procedures (LTP). The location and loadings from point source dischargers along each subsegment in this study were obtained from the 2001 discharger inventory. TMDLs for oxygen-demanding substances were calculated for Contraband Bayou, Bayou Choupique, West Fork/Houston River, and Bayou D'Inde based on the results of seasonal projection models. The results of the projection runs and the calculated TMDLs for each subsegment are shown below.

Contraband Bayou Subsegment 030305	**Summer (Mar-Nov)**	**Winter (Dec-Feb)**
Current Point Source Loadings (g/d BOD)	898,237	898,237
Current Nonpoint Source Loadings (g/d BOD)	2,247,749	2,274,489
Critical Conditions Point Source Loadings (g/d BOD)	898,237	898,237
Critical Conditions Nonpoint Source Loadings (g/d BOD)	827,516	997,934
Point Source WLA (g/d BOD)	898,237	898,237
Nonpoint Source LA (g/d BOD)	654,941	808,317
MOS (g/d BOD) [10 percent of TMDL]	172,575	189,617
Assimilative Capacity (g/d BOD)	1,725,753	1,896,171
Reserve Capacity (g/d BOD)	0	0
TMDL (g/d BOD)	1,725,753	1,896,171
TMDL (lbs/d BOD)	3,801	4,177

Bayou Choupique Subsegment 031001	**Summer (Mar-Nov)**	**Winter (Dec-Feb)**
Current Point Source Loadings (g/d BOD)	9,839	9,839
Current Nonpoint Source Loadings (g/d BOD)	28,426,117	28,527,208
Critical Conditions Point Source Loadings (g/d BOD)	9,839	9,839
Critical Conditions Nonpoint Source Loadings (g/d BOD)	27,784,061	32,870,904
Point Source WLA (g/d BOD)	9,839	9,839
Nonpoint Source LA (g/d BOD)	25,004,671	28,527,208
MOS (g/d BOD) [10 percent of TMDL]	2,779,390	3,170,780
Assimilative Capacity (g/d BOD)	27,793,900	32,880,743
Reserve Capacity (g/d BOD)	0	1,172,916
TMDL (g/d BOD)	27,793,900	31,707,827
TMDL (lbs/d BOD)	61,220	69,841
West Fork/Houston River Subsegments 030901 and 030806	**Summer (Mar-Nov)**	**Winter (Dec-Feb)**
Current Point Source Loadings (g/d BOD)	17,017	17,017
Current Nonpoint Source Loadings (g/d BOD)	7,105,125	6,442,373
Critical Conditions Point Source Loadings (g/d BOD)	17,017	17,017
Critical Conditions Nonpoint Source Loadings (g/d BOD)	5,009,197	3,601,786
Point Source WLA (g/d BOD)	17,017	17,017
Nonpoint Source LA (g/d BOD)	4,506,576	3,239,906
MOS (g/d BOD) [10 percent of TMDL]	502,621	361,880
Assimilative Capacity (g/d BOD)	5,026,214	3,618,803
Reserve Capacity (g/d BOD)	0	0
TMDL (g/d BOD)	5,026,214	3,618,803
TMDL (lbs/d BOD)	11,071	7,971
Bayou D'Inde Subsegment 030901	**Summer (Mar-Nov)**	**Winter (Dec-Feb)**
Current Point Source Loadings (g/d BOD)	2,672,018	2,672,018
Current Nonpoint Source Loadings (g/d BOD)	415,259	433,297
Critical Conditions Point Source Loadings (g/d BOD)	2,672,018	2,672,018
Critical Conditions Nonpoint Source Loadings (g/d BOD)	2,780,377	3,722,394
Point Source WLA (g/d BOD)	2,672,018	2,672,018
Nonpoint Source LA (g/d BOD)	415,259	433,297
MOS (g/d BOD) [10 percent of TMDL]	343,030	345,035
Assimilative Capacity (g/d BOD)	5,452,394	6,394,412
Reserve Capacity (g/d BOD)	2,022,087	2,944,062

TMDL (g/d BOD)	3,430,307	3,450,350
TMDL (lbs/d BOD)	7,556	7,600

MOS Margin of Safety
g gram
kg kilogram
d day
lb pound
BOD biochemical oxygen demand

Overall reductions in nonpoint source loadings required to meet the D.O. criteria in each subsegment are listed below.

Subsegment	Summer (March - November)	Winter (December - February)
030305 (Contraband Bayou)	71	61
030801& 030806 (West Fork & Houston River)	37	50
031001 (Bayou Choupique)	12	--[1]
030901 (Bayou D'Inde)	--[1]	--[1]

[1] D.O. criterion attained with no reductions in current nonpoint or point sources.

Attainment of the dissolved oxygen (D.O.) criteria for the subsegments modeled in this study will require focused management of nonpoint sources. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources. LDEQ will work with other agencies such as local Soil and Water Conservation Districts to implement agricultural best management practices (BMPs) in the watershed through 319 cost-share programs. Louisiana's Nonpoint Source Pollution Management Plan outlined the state's approach to nonpoint source pollution control. It describes the types of projects that have been and will be implemented, and it presents information on BMPs that have been determined to be technically feasible and effective in the reduction of pollutant loadings and runoff. In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. LDEQ will continue to monitor receiving waters to determine whether standards and criteria are being attained.

1.0 Introduction

In order to achieve the goals of the Clean Water Act (CWA), the U.S. Environmental Protection Agency (USEPA) is responsible for ensuring that technology-based controls are established and maintained for point sources that discharge into waterbodies (USEPA 1991). The USEPA has the authority to require water quality-based controls when technology-based controls are deemed insufficient in attaining water quality standards. For impaired waterbodies requiring water quality-based controls, the USEPA is authorized under Section 303(d) of the CWA to require states to develop total maximum daily loads (TMDLs) and to identify and report to the USEPA waterbodies that are impaired due to point and nonpoint sources. Provisions for the identification of waterbodies that do not meet water quality standards are set forth in the USEPA Water Quality Management and Planning Regulation (40CFR 130.7(b)). States are primarily responsible for setting, reviewing, revising, and enforcing standards, while the USEPA has the authority to approve or disapprove State standards (USEPA 1991). Federal water quality standards may also be promulgated by the USEPA where necessary (USEPA 1991). Routine assessments of water quality in waterbodies are required under Section 305(b) of the CWA.

As defined in 40 CFR 130.2, water quality-based controls primarily consist of load allocations (LAs), wasteload allocations (WLAs), and TMDLs. LAs describe that portion of the receiving water's loading capacity that is "attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources." WLAs describe that portion of the receiving water's loading capacity that is "allocated to one of its existing or future point sources of pollution." TMDLs are defined as "the sum of the individual WLAs for point sources and LAs for nonpoint sources and natural background." "Future" sources, as well as modeling uncertainty, seasonal variations in stream and discharge characteristics, and error introduced during sampling and analysis are commonly accounted for by applying an explicit Margin of Safety (MOS).

The State of Louisiana's current Section 303(d) list of impaired waterbodies was released on October 28, 1999 by the USEPA Region 6. This list was developed by the USEPA as a result of a Court Order against USEPA Region 6 on October 1, 1999. A court-ordered schedule for the completion of TMDLs for waterbodies listed on the 1999 303(d) list was established for the Mermentau, Vermilion-Teche, Calcasieu, Ouachita, Barataria, Terrebonne, Red, Sabine, Pontchartrain, Mississippi, Atchafalaya, and Pearl River Basins. Subsequently, and in order to comply with the court-ordered schedule for the completion of TMDLs, tributaries to the Calcasieu River that were listed on the 1999 303(d) list, including Contraband Bayou (Subsegment 030305), the West Fork of Calcasieu River (Subsegment 030801), and Bayou D'Inde (Subsegment 030901), were targeted by the Louisiana Department of Environmental Quality (LDEQ) for the development of TMDLs for dissolved oxygen (D.O.). In addition, tributaries to the Calcasieu River that were listed on the State of Louisiana's 2000 Section 305(b) list of waterbodies not fully supporting one or more uses were also targeted for TMDL development. These tributaries included Bayou Choupique and a the Houston River. Although not all of the waterbodies included in this TMDL study are technically classified as estuarine, the TMDL study has been designated as the "Calcasieu Estuary" due to the fact that the majority of the model coverage area is estuarine. The Calcasieu Estuary and the Calcasieu River Basin are, therefore, used interchangeably throughout the remainder of this report.

TMDLs for portions of the Calcasieu River Basin including Bayou D'Inde and portions of Contraband Bayou, West Fork Calcasieu River, and Bayou Choupique were originally developed in a TMDL study by Duke (1985). The 1985 model was expanded as part of this study to encompass upstream portions of subsegments 030305 (Contraband Bayou), 031001 (Bayou Choupique), and 030801 (West Fork) and a 3.8-kilometer (km) portion of Subsegment 030806 (Houston River). Load limitations for oxygen-demanding substances and goals for the reduction of those pollutants are presented in this report for Contraband Bayou, Bayou Choupique, West Fork, a portion of the Houston River, and Bayou D'Inde (Subsegment 030901). Contraband Bayou and Bayou D'Inde were also listed on the court-ordered list for nutrients. LDEQ's position, as supported by the declaratory ruling issued by Secretary Givens in response to the lawsuit regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. Documentation of model calibration for the expanded portions of the model and the development of seasonal projection models are provided. The sequence and format of this report were prepared in accordance with the 2001 LDEQ TMDL Louisiana Technical Procedures (LTP).

2.0 Study Area Description

2.1 Calcasieu River Basin

According to information provided by the LDEQ, the Calcasieu River Basin is approximately 10,126 square kilometers (km^2) in area and approximately 257.4 km in length. Surface waters in the northern part of the basin begin in pine forested hills and drain southward into brackish and saltwater estuarine areas. The Calcasieu River Basin is located in southwestern Louisiana. The Basin is bounded on the north and west by the Sabine River Basin, on the north by the Red River Basin, and on the east by the Mermentau River Basin. The Gulf of Mexico marks the southern boundary of the Calcasieu River. The Basin is approximately 10,126 km^2 in area and is approximately 257.4 km in length (LDEQ 1996). Surface water flows begin in the hills west of Alexandria, Louisiana and exit the basin at the Gulf of Mexico. The mouth of the Calcasieu River is approximately 48.27 km east of the Texas-Louisiana state border (LDEQ 1996).

The northern portion of the basin is forested and the southern part of the basin has estuarine characteristics. Land uses in the basin include agricultural, silvicultural, urban, and industrial. The area surrounding the City of Lake Charles consists primarily of urban and industrial land uses. Because previous studies have been conducted within the Calcasieu Basin, a detailed description of the basin has been developed by the LDEQ. Portions of this description are presented in the following paragraphs.

The Calcasieu River Basin encompasses the hill region of the state, the terrace region, and a section of the coastal marsh. The upper end of the basin consists of pine forested hills, while the lower end of the basin consists of brackish and salt marshes. Originally, much of the area was covered by tall prairie grasses, among which there were scattered clumps of trees (Soil Survey 1962).

The hill region includes the longleaf pine forests, maximum elevations and relief, dendritic and trellis drainage, interior salt domes, wolds or cuestas (hard sedimentary rock), ironstone, excellent surface and groundwater resources, mature soils, and the oldest rocks in the state. The soil types consist of coastal plain soils and flatwoods soils. Vegetation includes longleaf pine forests (longleaf pines, slash pines, some hardwoods) and bottomland hardwoods (cottonwood, sycamore, willow, water oaks, gum, maple, loblolly pine) (Kniffen 1988).

The terrace region includes intermediate elevations and relief, older alluvium, and a large percentage of tabular surfaces. The terraces range from flatwoods to prairies. The flatwoods consist of low relief, mixed longleaf forests, bagols, pimple mounds, dendritic drainage, and flatwoods soils. Vegetation includes flatwoods (longleaf pine, oak, palmetto, wiregrass), cypress forests (cypress, tupelo), and bottomland hardwoods. The prairies consist of low relief, prairie grassland, prairie soils, pimple mounds, dendritic streams, ice-age channels, and platens or marais (small, shallow undrained ponds in the prairies). Vegetative cover consists of prairie vegetation (bluestem, broomsedge), cypress forests, and bottomland hardwoods (Kniffen 1988). The coastal region includes fresh and salt/brackish marshes. It consists of muck and peat soils. Vegetation includes cattail, Roseau cane, three-corner grass, and other types of marsh grasses. The region exists in the lower end of the basin. Average annual precipitation in the segment is approximately 141 centimeters (cm), according to information presented by Kniffen (1988).

The slope of the land toward the Gulf is very gradual, especially in the coastal zone. Land use in the Calcasieu River Basin is largely agricultural, with many areas that have been impacted by industrial dischargers. Flows in many of the tributaries to the Calcasieu River approximate zero. This statement is not accurate for the Calcasieu River itself, which conveys substantial flows throughout the year. Because many waterbodies in the basin have minimal hydraulic gradients and slow flows, their reaeration potential is low.

Portions of the Calcasieu River Basin covered by this TMDL study, primarily those south of Interstate 10, are tidally influenced. These tides are influenced by wind action on Calcasieu Lake, Prien Lake, and Lake Charles. The Calcasieu River Saltwater Barrier, which is operated by the U.S. Army Corps of Engineers, is located approximately 4.0 km upstream of the Calcasieu River and Lake Charles confluence. The water surface elevation of some tributaries, specifically West Fork and Houston River, and reaches of the Calcasieu River are influenced by the operation of this structure.

Prior studies have shown nonpoint sources dominate the northern subsegments of the basin while a few municipal dischargers also exist in these areas. The nonpoint sources include runoff from pine forests, agricultural areas, and pastureland. Point source dischargers and saltwater intrusion dominate the southern subsegments of the basin below Lake Charles, Louisiana. The point source discharges primarily include industrial and municipal dischargers, with the highest concentration of industry being near the cities of Lake Charles, Westlake, and Sulphur.

Descriptions of the subsegments included in this study are presented in the following sections. Locations of the five subsegments included in this TMDL study are presented on Figure 1, Appendix H. The physical extents of model expansions for Contraband Bayou, Bayou Choupique, and the West Fork and Houston River are shown on Figure 2, Appendix H.

2.1.1 Subsegment 030305, Contraband Bayou

Subsegment 030305, classified as estuarine by LDEQ, is comprised of the entire 9.7-km reach of Contraband Bayou. The subsegment originates at its headwaters at McNeese State University and ends at the confluence with the Calcasieu River (Figure 3; Appendix H). According to the U.S. Geologic Survey (USGS) 7.5-minute topographic map of Lake Charles (1975), several unnamed tributaries discharge to Contraband Bayou. Contraband Bayou discharges to the Calcasieu River between Clooney Island and Coon Island loops. Contraband Bayou has a drainage area of approximately 39.6 km^2. The area surrounding Contraband Bayou has low relief, and land uses within its watershed are primarily urban and residential.

2.1.2 Subsegment 030801, West Fork Calcasieu River (West Fork)

Subsegment 030801, extending approximately 27.4 km, is comprised of the West Fork Calcasieu River (West Fork). The West Fork originates at the confluence of Beckwith Creek and Hickory Branch and discharges into the Calcasieu River north of the Goosport community (Figure 4, Appendix H). The subsegment is located in the central portion of the Calcasieu River Basin and northwest of the City of Lake Charles. According to the USGS 7.5-minute topographic map of Buhler, Louisiana (1975), several unnamed tributaries discharge into the West Fork. Major tributaries include the Little River and the Houston River, which discharge into the West Fork at approximately 8.0 and 12.9 km, respectively, downstream of the beginning of the subsegment. The West Fork subsegment has a drainage area of approximately 63.2 km^2.

The area surrounding West Fork generally has low relief, and land uses within the watershed primarily consist of agricultural crop production, rangeland, and forestry activities. Several areas within this subsegment have also been hydrologically modified by dredging, pump stations, and weir placement. Rural residential areas, primarily mobile home parks, are located in the area surrounding West Fork near the central portion of the subsegment. Recreational areas such as Holbrook Park and Sam Houston Jones State Park are found near the stream. The area surrounding West Fork near the confluence with the Calcasieu River consists primarily of swampland.

2.1.3 Subsegment 030806, Houston River

Subsegment 030806 consists of the Houston River from the junction of Bear Head Creek at Parish Road to the West Fork of the Calcasieu River. This subsegment is approximately 399 km^2 in area. The Houston River flows approximately 46.7 km from west to east and is influenced by the Salt Water Barrier located on the Calcasieu River. TMDLs for D.O. were previously developed for the majority of the Houston River by LDEQ (2001). Therefore, only 3.8 km of the Houston River are included in this study. The model segment extends from the confluence with West Fork to 3.8 km upstream of this confluence (Figure 4, Appendix H). According to the USGS 1:100, 000-scale topographic map of Lake Charles, Louisiana (1986), several unnamed tributaries discharge into the Houston River. Major tributaries include the Houston River Canal, Buxton Creek, Persimmon Gulley, and Middle Gulley located approximately 12, 26, 34, and 54 km, respectively, upstream of the beginning of the segment. Land uses within Subsegment 030806 consist primarily of forestland, agricultural land, and rangeland. Approximately 12 percent of the subsegment is comprised of wetland (LDEQ 2001).

2.1.4 Subsegment 030901, Bayou D'Inde

Subsegment 030901, classified as estuarine by LDEQ, is comprised of the entire 22.2 km reach of Bayou D'Inde as the main stem. The subsegment originates at the headwaters near the City of Sulphur and ends at the confluence with the Calcasieu Ship Channel. According to the USGS 1:100,000-scale topographic map of Lake Charles (1986), major tributaries include Little Bayou D'Inde and Maple Fork approximately 10 and 4 km, respectively, upstream of the confluence with the Calcasieu Ship Channel. Subsegment 030901 has a drainage area of approximately 85.3 km^2. The area surrounding Bayou D'Inde has low relief, and land uses primarily consist of urban and industrial.

2.1.5 Subsegment 031001, Bayou Choupique

Subsegment 031001, classified as estuarine by LDEQ, is comprised of the entire 32.2-km reach of Bayou Choupique as the main stem. The subsegment originates at the headwaters west of the City of Sulphur and ends at the confluence with the Intracoastal Waterway northwest of Calcasieu Lake (Figure 5, Appendix H). According to the USGS 1:100,000-scale topographic map of Lake Charles (1986), several unnamed tributaries discharge to Bayou Choupique. Major tributaries include Spring Gully and Wing Gully discharging into Bayou Choupique at approximately 17.7 and 24.1 km, respectively, upstream of the confluence with the Intracoastal Waterway. Subsegment 031001 has a drainage area of approximately 264.1 km^2. The area surrounding Choupique Bayou has low relief, and land uses primarily consist of agricultural, including irrigated and non-irrigated crop production and pastureland.

2.2 Water Quality Standards

Water quality standards for the State of Louisiana have been defined according to the designated uses of the waterbodies (LDEQ 2000). Both general narrative standards and numerical criteria have been defined. General standards include prevention of objectionable color, taste, and odor and limits for solids, toxic compounds, oil and grease, foam, and nutrients, as well as for aesthetic degradation. Numerical criteria and designated uses for the subsegments included in this TMDL study are presented in Table 1.

Table 1. Numerical Criteria and Designated Uses

Subsegment	Mainstream	Designated Uses	Cl (mg/L)	SO_4 (mg/L)	D.O. (mg/L)	pH	BAC	Temp. (°C)	TDS (mg/L)
030801	West Fork	A B C F	250	75	(1)	6.0-8.5	1	34	500
031001	Bayou Choupique (Estuarine)	A B C	N/A	N/A	4.0	6.0-8.5	1	35	N/A
030806	Houston River	A B C F	250	75	(1)	6.0-8.5	1	32	500
030305	Contraband Bayou (Estuarine)	A B C	N/A	N/A	4.0	6.0-8.5	1	35	N/A
030901	Bayou D'Inde (Estuarine)	A B C	N/A	N/A	4.0	6.0-8.5	1	35	N/A

Cl chlorides
SO_4 sulfates
D.O. dissolved oxygen
BAC bacterial criterion
TDS total dissolved solids
A Primary Contact Recreation
B Secondary Contact Recreation
C Propagation of Fish & Wildlife
F Agriculture
1 Bacterial Criterion Applicable to Primary Contact Recreation
(1) Designated Naturally Dystrophic Waters Segment; Seasonal D.O. Criteria: 5.0 milligrams per liter (mg/L) December-February, 3.0 mg/L March-November.
N/A Not applicable.

Designated uses for West Fork and the Houston River (Subsegments 030801 and 030806) consist of primary and secondary contact recreation, fish and wildlife propagation, and agricultural. These subsegments also have seasonal D.O. criteria of 5.0 mg/L during the winter (December through February) and 3.0 mg/L during the summer season (March through November). The three estuarine subsegments, Contraband Bayou, Bayou D'Inde, and Bayou Choupique, have a year-round D.O. standard of 4.0 mg/L. Designated uses for these subsegments include primary and secondary contact recreation and fish and wildlife propagation. Numerical criteria for chlorides, sulfates, and total dissolved solids are not applicable to these waterbodies.

2.3 Wastewater Dischargers

An extensive file search was conducted by ARCADIS and LDEQ personnel to locate and update known oxygen-demanding point source dischargers within the areas covered by the 1985 TMDL study and the new model expansion areas. The file review included the collection of data from National Pollutant Discharge Elimination System/Louisiana Pollutant Discharge Elimination System (NPDES/LPDES) files, permit applications, and inspection reports. Data obtained as a result of the file review included the following:

- Facility Name
- EPA ID Number
- Permit Number
- Company Name
- SIC Code
- Facility Type
- Location
- Receiving Stream
- UTM-Northing
- UTM-Easting
- Treatment Type
- Treatment Limits (BOD_5/$CBOD_5$, NH_3-N, D.O., TEMP)
- Anticipated Flow
- Action (with regard to inclusion in TMDL)

LDEQ personnel developed classification codes for the dischargers upon completion of the discharger inventory. As provided, the classification codes served as the primary basis for the inclusion or exclusion of a discharger in the calibration and projection models. The classification codes provided by LDEQ are as follows:

- 1A – Include in estuary model;

- 1B – Include in tributary model;
- 2 – Flow not significant enough for inclusion in modeling analysis; but requires allocation (A = estuary, B = tributary); and
- 3 – Flow not significant enough to model and not in a 303(d) subsegment or not a discharger with a D.O. impact.

The availability of discharge monitoring reports (DMRs) for point dischargers located along expanded segments was determined to be very limited. Also, no measured flow or water quality data were available for the calibration period discussed in this report. Therefore, discharger permits served as the primary source of information for discharger mass loadings. The discharger inventory is presented in Table 1, Appendix J. A complete listing of the Northing and Easting locations for the dischargers that are located along each subsegment in this study are presented in Table 2, Appendix J.

2.4 Water Quality Conditions/Assessment

Water quality conditions are monitored by LDEQ using fixed station sampling locations, intensive surveys, inspection programs, and special studies on various waterbodies throughout the state. Data obtained from these sources are assessed in an effort to determine if water quality standards and criteria are met. A water quality assessment was conducted by LDEQ in 2000 for the subsegments included in this TMDL study. This assessment was based on data collected between 1995 and 1999. With the exception of Bayou Choupique and the Houston River, each of the subsegments included in this TMDL study are listed on the 1999 court-ordered 303(d) list of impaired waterbodies.

2.4.1 Subsegment 030305, Contraband Bayou

This subsegment is designated by LDEQ as only partially meeting overall use support. LDEQ determined during the year 2000 assessment that primary contact recreation and fish and wildlife propagation uses were not being supported. Suspected causes are identified as organic enrichment/low D.O. and pathogens. Suspected sources are municipal point source discharges as well as urban runoff and contributions from storm sewers.

2.4.2 Subsegment 030801, West Fork Calcasieu River (West Fork)

This subsegment is designated by LDEQ as meeting all designated uses, except fish and wildlife propagation. LDEQ has also classified this subsegment as naturally dystrophic. Suspected causes are identified as copper, lead, metals, and organic enrichment/low D.O. Suspected sources are hydromodification and forestry activities as well as other natural and unknown sources.

2.4.3 Subsegment 030806, Houston River

This subsegment is designated by LDEQ as meeting all designated uses, except fish and wildlife propagation. LDEQ has classified this subsegment as naturally dystrophic. Suspected causes are identified as organic enrichment/low D.O., pH, salinity/total dissolved solids (TDS)/chlorides and sulfates. Suspected sources of impairment include natural sources, hydromodification, and agricultural activities

2.4.4 Subsegment 030901, Bayou D'Inde

This subsegment is designated by LDEQ as only partially meeting overall use support. LDEQ determined during the year 2000 assessment that the primary contact recreation and fish and wildlife propagation uses were not being supported. Suspected causes are identified as PCBs and priority organics, as well as organic enrichment/low D.O. Suspected sources are municipal and industrial point sources and urban runoff from storm sewers.

2.4.5 Subsegment 031001, Bayou Choupique

This subsegment is designated by LDEQ as only partially meeting overall use support. LDEQ determined during the year 2000 assessment that the fish and wildlife propagation use was not being supported. Suspected causes are identified as cadmium, copper, lead, and metals, as well as organic enrichment/low D.O. Suspected sources are agricultural and natural sources.

2.5 Prior Studies

Between 1974 and the present, the Calcasieu River Basin has been the subject of seven water quality studies. A detailed discussion of each study was provided by Duke (1985). Each of the studies are listed and briefly described below.

- A WLA study prepared for the Louisiana Health and Social and Rehabilitation Services Administration (Roy F. Weston, Inc. January 18,1974). The study focused on the entire Calcasieu River Basin;

- A water quality management plan that was prepared for the Louisiana Health and Social and Rehabilitation Services Administration (Roy F. Weston, Inc. March 1974). The study focused on the entire Calcasieu River Basin;

- A water quality modeling and WLA study was prepared for the Louisiana Department of Natural Resources (Hydroscience, Inc. 1980). The study focused on the entire Calcasieu River Basin;

- A water quality modeling and WLA study prepared for Lakeside Industrial Relations and Services (AWARE, Inc. 1981). The study focused on portions of the Calcasieu River Basin downstream of the saltwater barrier. The RECEIV-II (Raytheon 1974) water quality model was first applied to the Basin during this study;

- A WLA study based on the original AWARE modeling study was performed by Roy F. Weston, Inc.. Only undated and partial documentation were available at the time Duke conducted his research (Duke 1985);

- A water quality modeling and TMDL study was prepared for the LDEQ (Duke 1985). The study expanded upon the modeling network established by AWARE and Weston and the RECEIV-II model was used. The model was expanded to include upstream reaches and tributaries of the Calcasieu River near Lake Charles, Louisiana; and

- The current TMDL study as described in this report.

3.0 Documentation of Calibration Model

3.1 Program Description

TMDLs for the subsegments in this study were developed using the RECEIV-II water quantity and quality model. The RECEIV-II model was previously applied to the Calcasieu River below the Salt Water Barrier by AWARE, Inc. in 1981 as part of a water quality modeling and WLA analysis. Later, according to Duke (1985), Roy F. Weston conducted a WLA study for the Calcasieu Estuary using the RECEIV-II model (the study is undated). In 1985, Duke applied the RECEIV-II model to portions of the Calcasieu River Basin for the purpose of developing TMDLs for D.O. The modeling network, established as part of the 1985 study, was extended farther upstream in the Bayou Contraband, Bayou Choupique, and West Fork/Houston River tributaries as part of this study.

The RECEIV-II model was originally developed by Raytheon Oceanographic and Environmental Services for the USEPA during the New England Basins Modeling Project (USEPA Contract No. 68-01-01890). The RECEIV-II model is a two-dimensional, unsteady-state model and is capable of simulating tidal conditions, conservative and non-conservative constituents, and point discharges from multiple, geographically grouped sources (Raytheon Company 1974). The RECEIV-II model was adapted and modified from the Receiving Water Block of the Storm Water Management Model (SWMM). The model was first written in FORTRAN IV and was later converted to FORTRAN 90.

3.2 Input Data Documentation

For the purposes of this study, the 1985 RECEIV-II model was maintained without modification except for expansions to three subsegments. Expansions included upstream portions of Contraband Bayou, Bayou Choupique, and West Fork/Houston River. No expansion of the Bayou D'Inde model network was performed as part of this study. LDEQ conducted calibration field surveys on June 26 and 27, 2001, for Contraband Bayou, Bayou Choupique, West Fork, and a portion of the Houston River. Data collected during these surveys included *in-situ* measurements, water quality, and flow data. *In-situ* measurements included pH, D.O., temperature, conductivity, Secchi depth, depth of flow, and width of flow. Water quality data were collected in the morning and evening on the West Fork and Houston River. High and low tide water quality data were collected on the estuarine subsegments (Contraband Bayou and Bayou Choupique). Water quality parameters included total phosphorus (TP), total Kjeldahl nitrogen (TKN), ammonia-nitrogen (NH_3-N), nitrite + nitrate-nitrogen (NO_2+NO_3-N), Chlorophyll-*a* (Chl-*a*), and ultimate (60-day) carbonaceous biochemical oxygen demand (UCBOD). Additional field data included cross sections and global positioning system locations for flow measurement and water quality sampling sites. Flow measurements were available for sites that monitored tributaries to the modeled stream segments. In addition, five continuous monitor stations were deployed in each stream and temperature, conductivity, vented depth, D.O., and pH data were collected every 15 minutes. Data collected during the calibration survey are provided in Appendix F and the locations for collection of these data are shown on Figures 3 through 5, Appendix H.

The RECEIV-II model requires input to major data decks: setup, quantity, and quality. An additional data deck, the control data deck, allows the user to specify either quantity or quality simulations, or both. Input to the control data deck remained unchanged between the calibration and model projection runs. A discussion of input data for each data deck is provided in subsequent sections.

Data input to the RECEIV-II model is accomplished through a link-node spatial network for modeled segments. The link-node network used in the previous TMDL study by Duke (1985) was extended through the addition of nodes in Contraband Bayou, Bayou Choupique, and West Fork/Houston River (Figure 2, Appendix H). Schematics of each segment showing the location of expansion nodes are provided on Figures 6 though 8, Appendix H.

3.2.1 System Segmentation

The system segmentation of the Calcasieu estuary model is shown on Figure 2, Appendix H. New nodes were added to upstream portions of Bayou Contraband, Bayou Choupique, and West Fork/Houston River as shown. Descriptions of updates to the system segmentation performed during this study are outlined below.

- Seven nodes (121 through 127) were added to Bayou Choupique between Node 107 and U.S. Highway 90;

- Two nodes (119 and 120) were added to Bayou Contraband between Node 113 and Kirkman Street;

- Four nodes (115 through 118) were added to West Fork between Node 94 and the confluence of Beckwith and Hickory creeks; and

- One node (128) was added to Houston River upstream of the confluence with West Fork (Node 115).

3.2.2 Input to Setup Data Deck

The setup data deck allows for the specification of mass loadings to the model nodes. Mass loadings from stream tributaries and permitted point discharges were specified at the nearest model node. Each point source discharging to the model segments in this study were assigned model input references as listed in Table 1, Appendix J. Flow and water quality data for point sources were obtained from the LDEQ LPDES permit inventory previously discussed in Section 2.3 of this report. In all cases, input for discharge water quality concentrations corresponded with permit limitations. The anticipated flow rates listed for each discharge permit were used as input to the model. The permit concentrations and flow rates were determined to represent a “worst-case” scenario under season critical conditions at current permit limitations. The setup data decks of the calibration and TMDL model are provided in Appendix B.

Flow data for tributary site locations were used as input to the calibration model (Appendix E). Modeled simulations of tidal influences were calibrated against depth data for the continuous monitoring stations.

3.2.3 Input to Quantity Data Deck

The quantity data deck allows the user to specify options for the simulation of hydrodynamic parameters. Input to the quantity data deck remained unchanged between the calibration and model projection runs. Fifty-day cycles were specified to ensure that the model met dynamic equilibrium (steady-state). Because calibration data were collected over a 2-day period (June 26 to 27, 2001), the model simulation was specified for a 48-hour period. A 1-hour time-step was specified for water quality computations; a 120-second time-step was specified for water quantity computations.

Tidal influences on the modeled segments during the calibration period (June 26 to 27, 2001) were simulated by entering stage measurements from three tidal monitoring stations (Table 2). These stations included U.S. Army Corps of Engineers Gages 73472 (SWB-E), 73473 (SWB-W), and 76960 (Calc. Lock W). Gage 73472 is located east of and Gage 73473 is located west of the Calcasieu River saltwater barrier (near model Nodes 92 and 88, respectively). Gage 76960 is located west of the Calcasieu Lock and near model Node 29. The calibration model for this study and the 1985 study uses the tidal stage data for Node 29 as the driving tide at Node 32, due to their relative proximity. The distance between Nodes 29 and 32 was determined not to have a sizeable affect on hydrodynamic simulations. Data for these sites are posted on the USGS website (www.usgs.gov) and are also provided in Appendix G.

Table 2. Tidal Gage Descriptions and Corresponding Nodes for Calcasieu Estuary Model

Tidal Gage Description	Model Tidal Node
Calcasieu Salt Water Barrier – East (73472)	92
Calcasieu Salt Water Barrier – West (73473)	88
Intracoastal Waterway at Calcasieu Lock - West (76960)	32

Tributary flows to the modeled segments were entered into the model as discharges to nodes. Tributary flows and associated model identifications are provided in Table 1, Appendix E. Tributary flows for the calibration period were measured during the collection of survey data on June 26 and 27, 2001. Hydrogeometric data (Appendix F) collected during the calibration survey served as additional input to the quantity data deck.

3.2.4 Input to Quality Data Deck

Water quality data collected during the calibration period were used as input for tributary flows into the modeled segments. The model was calibrated against measured water quality data for locations within the model segments. In order to calibrate the model within the limits of the available data, the effects of tidal mass exchange between the lower estuary (as modeled by Duke [1985]) and the model segments were eliminated by disconnecting the expanded model segments from the original (1985) model network. During calibration of the model, the most downstream node of each model segment (94, 107, and 113) was identified in the model as a tidally forced node. The water quality concentrations of the nearest sampling site were assigned to each tidally forced node.

3.2.5 Input Data for Model Calibration

Calibration of the model was completed in two phases: hydrodynamic calibration followed by the calibration of water quality parameters. For the hydrodynamic calibration, input data for each node included the following variables: surface area, depth of node bottom from datum plane, length of each channel between nodes, width of each channel, average depth of channel, initial velocity, and flows from tributaries and point sources. The Manning coefficient (n) was selected as the hydrodynamic calibration term. The hydrodynamic calibration of the model was based on the simulation of water depth and flow at each continuously monitored station (LC 1 through 5). During the hydrodynamic calibration, the channel between Nodes 88 and 92 was eliminated to simulate the effects of saltwater barrier manipulations on the West Fork/Houston River model segment. Also, the model was executed for 900 time cycles (days) so that dynamic equilibrium (steady-state) analysis was achieved. Following hydrodynamic calibration, the channel between Nodes 88 and 92 was restored.

For the calibration of water quality parameters, input data for each node included the following variables: total nitrogen, TP, NH_3-N, NO_2+NO_3-N, UCBOD, Chl-*a*, D.O., salinity, and temperature. Date measurements and analysis results from the June 2001 field survey (Appendix F) served as input data for the surveyed streams. Calibration terms for water quality constituents included ammonia oxidation, nitrite oxidation, UCBOD oxidation, sediment oxygen demand (SOD), reaeration rate, and algal growth rate. The selected calibration parameters were consistent with those used by Duke for the 1985 TMDL study. Reaeration rates for model segments were computed using the Covar method (Covar 1976). In accordance, the O'Connor-Dobbins Equation (O'Connor and Dobbins 1958) was selected for the computation of reaeration rates based on the ranges of velocities and depths encountered during the calibration survey. The selection of the O'Connor-Dobbins Equation facilitated the hourly re-computation of reaeration rates based on fluctuating stream depths and velocities. These methods are further discussed in *Rates, Constants, and Kinetics Formulations,* Surface Water Quality Modeling (2nd Ed.) (Tetra Tech 1985).

The calibration of water quality parameters in new model segments required that each new model segment be disconnected from the downstream portion of the estuary model. This modification to the model allowed for a better representation of the water quality in the new segments without the effect of water quality concentrations in the downstream portion of the system. The channels eliminated for this purpose included channels between Nodes 106 and 107, 104 and 107, 93 and 94, and 87 and 113. The most downstream node of each new model segment (Nodes 94, 107, and 113) was next designated as a tidal junction node for the calibration of water quality parameters. Model output from the hydrodynamic calibration phase was then used as input data for the new tidal junction nodes. Water quality data for sample sites corresponding with the location of the new tidal junction nodes (Sample Sites WF1, CP1, and CB1) were used as water quality input for the new tidal junction nodes. Tidal exchange ratios at each tidal junction node were set at 0.0 to represent the fraction of total mass leaving the system on the outgoing tide that returns on the incoming tide. The input data for the calibration model (2K2Cal.dat) are provided in Appendix C.

3.3 Model Discussion and Results

The output data for the calibration model (2K2Cal.out) is provided in Appendix C. Results of the hydrodynamic simulation for each model segment were determined to be acceptable based on the simulation of general stage fluctuations and flow to and from the model segment. Results of the stage simulations for each model segment are shown on Figure 1. Ranges of the Manning coefficient used in the hydrodynamic calibration are shown in Table 3.

Calibration ranges for the water quality constituents are shown in Table 3. The simulated D.O. concentrations for each model segment were determined to be acceptable and within the ranges of D.O. concentrations measured during the summer field survey. Results of the simulated versus measured D.O. concentrations are shown on Figure 2.

Table 3. Parameter Ranges for Calibration Model

Parameter (units)	**Range**	
	2001 Study Segments	**1985 Study Segments**
Manning coefficient, n (none)	0.024 – 0.030	0.018 – 0.035
Ammonia oxidation (d^{-1})	0.0002 – 0.002	0.002 – 0.020
Nitrite oxidation (d^{-1})	1.00	1.00
BOD oxidation (d^{-1})	0.001 – 0.010	0.001 – 0.050
Benthal or sediment oxygen demand ($g/m^2/d$)	0.75 – 6.80	0.75 – 1.50
Reaeration rate (d^{-1})	Variable(1)	0.003 – 2.000(2)
Algal growth rate (d^{-1})	0.15 – 0.50	0.15

(1) Reaeration rate was re-computed hourly, based on water depth and velocity and according to the O'Connor-Dobbins Equation.

(2) Reaeration rate was explicitly specified and constant for model segments.

$g/m^2/d$ Grams per square meter per day.

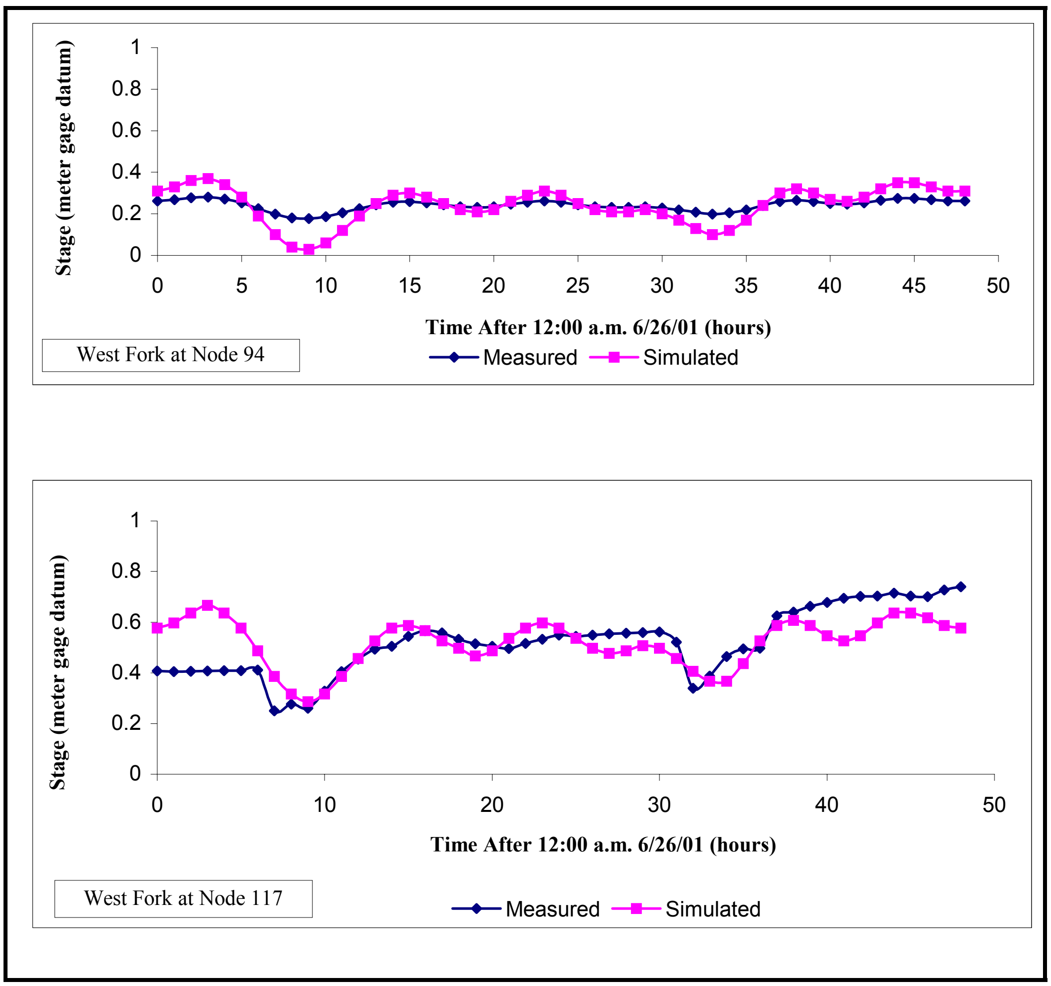

Figure 1. Results of Hydrodynamic Calibration

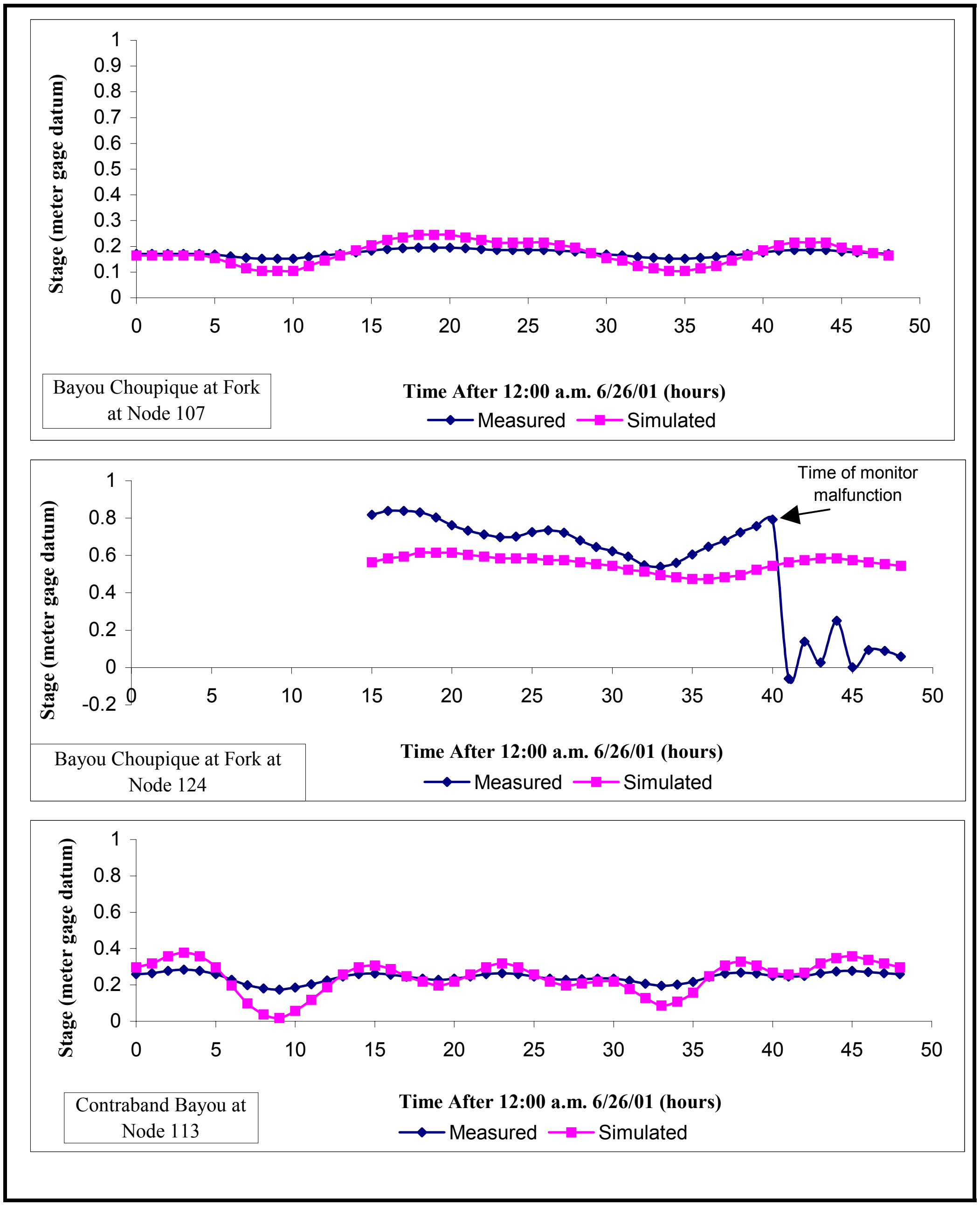

Figure 1. Results of Hydrodynamic Calibration (continued).

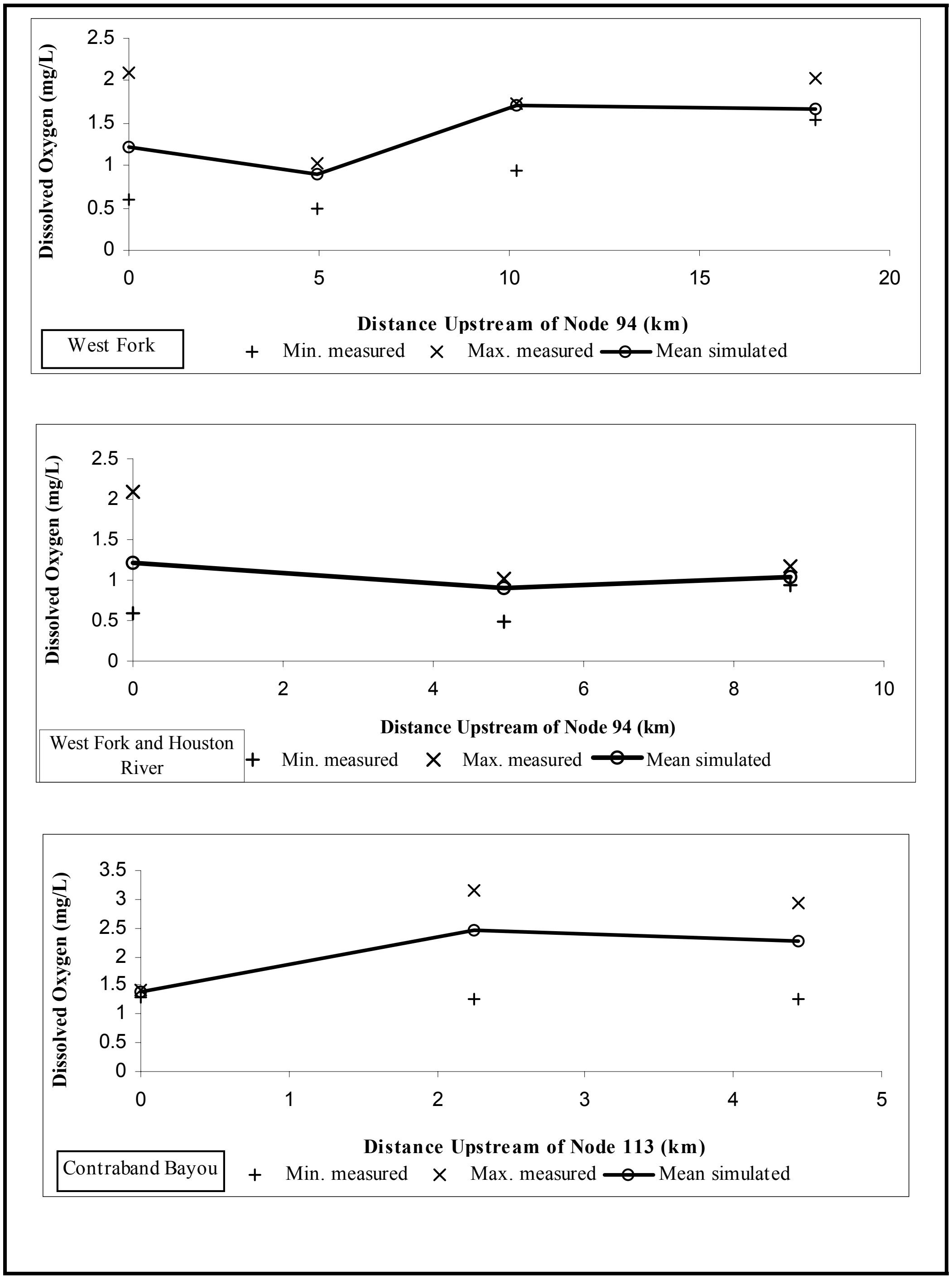

Figure 2. Results of Model Calibration for Dissolved Oxygen.

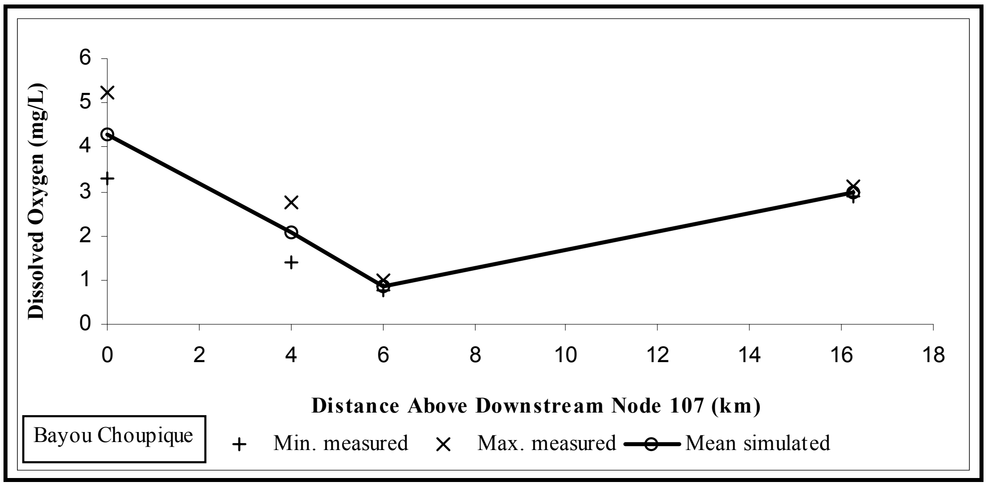

Figure 2. Results of Model Calibration for Dissolved Oxygen (continued).

4.0 Water Quality Projections

4.1 Critical Conditions, Seasonality, and Margin of Safety

Guidance provided by the USEPA states that "TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters (40 CFR 130.7 (c) (1)). LDEQ provides further guidance in defining "critical conditions." LDEQ defines critical conditions in terms of background flow rate and stream temperature (LDEQ 2001). Critical conditions are further specified for the summer and winter seasons as follows:

- Summer Season Critical Conditions:

  The 7Q10 flow rate or 0.0028 cubic meter per second (cms; 0.1 cubic feet per second [cfs]), whichever is greater. Background temperature of 30° Celsius or the 90th percentile of daily water temperatures when appropriate data are available.

- Winter Season Critical Conditions:

  The 7Q10 flow or 0.0283 cms (or 1 cfs), whichever is greater. Background temperature of 20° Celsius or the 90th percentile of daily water temperatures, when appropriate data are available.

Summer and winter season 7Q10 flows were provided by LDEQ for tributaries to modeled segments. Exceptions included flows for the Wing Gully and Spring Gully tributaries to Bayou Choupique, due to the absence of flow monitoring data on these streams. Flows for these streams were calculated based on the following equation.

$$Q_{Upstream} = Q_{Downstream} - \Sigma\,(Q_n + Q_{n+1} + \ldots) \tag{1}$$

where $Q_{Upstream}$ = 7Q10 for upstream node of new model segment (cms);

$Q_{Downstream}$ = 7Q10 for downstream node of new model segment (cms);

Q_n = point source discharge flow rate (cms);

n = number of point source dischargers

Historical temperature data for the modeled segments were obtained from LDEQ records for ambient monitoring stations in the Statewide Ambient Water Quality Network (www.deq.state.la.us; Appendix G). The locations of the nearest LDEQ monitoring stations for each model segment are shown on Figures 3 through 5, Appendix H. Monthly water temperature data for bayous Contraband (LDEQ Monitor 824) and Choupique (LDEQ Monitor 849) were available for only one year (1999), and monthly temperature data for West Fork was available for between 1971 and 1999. Due to the limited data available for bayous Contraband, Choupique, and D'Inde, the 90th percentile of water temperatures reported for West Fork (LDEQ Monitor 092) between 1991 and 1999 were calculated and applied to the West Fork model segment as well as bayous Contraband, Choupique, and D'Inde. The 90th percentile water temperatures for summer (May though October) and winter (November through April) were as follows.

- Summer season stream temperature = 30.2° Celsius; and
- Winter season stream temperature = 19.4° Celsius.

A conservative approach in calculating TMDLs for a stream or reach provides some assurance that the model accounts for uncertainty, seasonal variations, growth, and error. For Louisiana streams, LDEQ TMDL technical procedures (LDEQ 2001) recommend performing projection analyses at the 7Q10 flow and the 90th percentile of empirical temperature data. These analyses assume that both conditions occur simultaneously. In addition, an explicit MOS is commonly applied. For subsegments modeled in this study, specific guidance was provided by LDEQ for the application of MOSs to TMDL loadings. The guidance provided and methodology used in calculating the MOS for each subsegment were as follows:

- An explicit MOS was applied to each subsegment equal to 10 percent of the TMDL for the subsegment;

- Where no reserved capacity was available in the modeled subsegments, the MOS was subtracted from the nonpoint source loading at critical conditions. The resulting load was designated as the Nonpoint Source Load Allocation (LA).

In previous TMDL studies, LDEQ has applied a standard 20 percent MOS to subsegment loadings. The rationale for using less than the standard MOS for the subsegments included in this study was as follows:

1. The TMDL is based on the calibrated model from the 1985 TMDL study. The model was expanded by the 2001 acquisition of additional tributary data. The degree of confidence in the model is somewhat less than the degree of confidence associated with a recently calibrated model; and

2. The projection model was executed for 900 time cycles (days) at season critical conditions to ensure that a dynamic equilibrium had been achieved. It is an extremely conservative assumption that the subsegments would remain at season critical conditions of flow and temperature for this consecutive period of time.

4.2 Input Data Documentation

Prior to model projection runs, the calibrated model (2K2Cal.dat) was modified to reconnect expansion segments to the model network used by Duke (1985) to facilitate the calculation of TMDLs for each subsegment. Reconnection of the expansion segments required the restoration of Channel 141 for West Fork/Houston River, Channels 154 and 155 for Bayou Choupique, and Channel 161 for Contraband Bayou. The reconnected calibration models for summer and winter conditions were renamed 2K2CalS.dat and 2K2CalW.dat, respectively (Appendix D).

Model projections were performed for summer and winter critical conditions. The calibration model was modified for this purpose in the following ways:

1. Headwater flows were modified to reflect critical condition flows, as shown in Table 1, Appendix E; and

2. Temperatures were modified to reflect the 90th percentile of historical, measured temperatures.

For headwaters where TMDL models are already available, in this case the Houston River and Little River, flows corresponded with those reported in the respective TMDL output files. For headwaters where no TMDL model was available, the 7Q10 flows were used as input to the projection model. When no 7Q10 flow was available due to insufficient historical flow observations, in this case Spring Gully, Wing Gully, and Bayou D'Inde, an algebraic equation was used to calculate flows or LDEQ-recommended critical flows were used. The algebraic equation considers flows from the 1985 TMDL model (Duke 1985) and additional flows to the model segments due to the expansion of the model (Section 4.1, Equation 1). When 7Q10 flows or algebraically derived flows fell below the minimum seasonal critical flows provided in the LDEQ TMDL LTP, the minimum flows were used for input to the model. In all cases, concentrations of water quality parameters in headwater flows remained unchanged from the calibration model input. Flows and water quality concentrations for point dischargers also were obtained from permit limits listed in the 2001 discharger inventory (Appendix J). A conservative assumption of 2.0 mg/L D.O. was used for the modeled discharger flows based on the information provided in the inventory. Flow inputs for model projections are shown in Table 1, Appendix E. The 90th percentile of seasonal temperature conditions were calculated and entered into the model as discussed in Section 4.1.

Seasonal projection models were developed for each subsegment in this study by incorporating those portions of each subsegment that were originally included in the 1985 model with the expanded portions of the calibrated model that were completed as part of this study. A listing of the nodes included in each subsegment is provided below:

- Contraband Bayou – Nodes 9, 87, 112, 113, 119, and 120;

- Bayou Choupique – Nodes 105, 106, 107, 121, 122, 123, 124, 125, 126, and 127;

- West Fork/Houston River – Nodes 92, 93, 94, 115, 116, 117, 118, and 128; and
- Bayou D'Inde – Nodes 14, 83, 101, and 102.

Successive model projection runs for critical conditions for the upstream portions were performed by adjusting the SOD rate at each node until the D.O. criteria for each subsegment was met The seasonal projection models are listed as 2K2TMDLs.dat and 2K2TMDLw.dat (Appendix D). In the RECEIV-II model, the SOD term combines natural and anthropogenic nonpoint sources. The D.O. criteria for each subsegment in this study were discussed in Section 2.2 of this report. UCBOD for each subsegment was calculated by summing the UCBOD and nitrogenous biochemical oxygen demands (NBOD). The UOD was calculated as follows.

$$UOD = UCBOD_{60} + NBOD \text{ (mg/L)} \qquad (2)$$

where $UCBOD_{60}$ = 60-day ultimate carbonaceous biochemical oxygen demand concentration (mg/L)

$NBOD = 4.57 \times NH_3\text{-}N$ = nitrogenous biochemical oxygen demand concentration (mg/L)

$NH_3\text{-}N$ = total ammonia nitrogen concentration (mg/L)

The $UCBOD_{60}$ contributions included point source discharges and SOD.

The percent reduction in current loadings required to meet the D.O. criteria at season critical conditions was calculated by comparing outputs from the calibration and projection models. For this reason, the calibration model was run with the same headwater flows and background temperatures as the projection model. This modification of the calibration model was determined to more accurately represent loadings to the modeled segments under critical conditions. The percent reductions were then calculated according to the following equation:

Percent Reduction in Load =

$$[(\text{Current Load} - \text{Load Allocation}) / \text{Current Load}] \times 100 \qquad (3)$$

4.3 Model Discussion and Results

Input and output for the winter and summer projection models and for the calibration model run with critical flows and temperatures are provided in Appendix D. A listing of the output filenames is provided in Table 4. Input filenames correspond with respective output filenames but have .dat file extensions.

Table 4. Listing of Calcasieu Estuary TMDL Study Output Files and Descriptions for Seasonal Projection Models.

RECEIV-II Output Filename	Description
2K2TMDLs.out	Model projection with summer critical condition flows and background temperatures.
2K2TMDLw.out	Model projection with winter critical condition flows and background temperatures.
2K2CalS.out	Calibration model with summer critical condition flows and background temperatures.
2K2CalW.out	Calibration model with winter critical condition flows and background temperatures.

4.4 Calculated TMDL, WLAs, and LAs

Oxygen-demanding loads were allocated among point sources (WLAs) and nonpoint sources (LAs) based on the calculated UOD for each subsegment. The WLAs, LAs, and MOS for each loading type are listed for each modeled subsegment in Table 5. Detailed TMDL calculations are provided in Appendix A. No determination of anthropogenic versus natural nonpoint source demands could be made based on the available field and analytical data. In the RECEIV-II model, oxygen demand due to anthropogenic and natural nonpoint sources are combined into one term, the benthal or SOD rate. As discussed in Section 4.1, an MOS for each subsegment was assigned to allow for model uncertainty, seasonal variations, future growth, and error.

Table 5. Summary of TMDLs, WLAs, LAs, and MOSs for Subsegments 030305, 031001, 030801, 030806, and 030901.

Contraband Bayou Subsegment 030305	**Summer (Mar-Nov)**	**Winter (Dec-Feb)**
Current Point Source Loadings (g/d BOD)	898,237	898,237
Current Nonpoint Source Loadings (g/d BOD)	2,247,749	2,274,489
Critical Conditions Point Source Loadings (g/d BOD)	898,237	898,237
Critical Conditions Nonpoint Source Loadings (g/d BOD)	827,516	997,934
Point Source WLA (g/d BOD)	898,237	898,237
Nonpoint Source LA (g/d BOD)	654,941	808,317
MOS (g/d BOD) [10 percent of TMDL]	172,575	189,617
Assimilative Capacity (g/d BOD)	1,725,753	1,896,171
Reserve Capacity (g/d BOD)	0	0
TMDL (g/d BOD)	1,725,753	1,896,171
TMDL (lbs/d BOD)	3,801	4,177
Bayou Choupique Subsegment 031001	**Summer (Mar-Nov)**	**Winter (Dec-Feb)**
Current Point Source Loadings (g/d BOD)	9,839	9,839
Current Nonpoint Source Loadings (g/d BOD)	28,426,117	28,527,208
Critical Conditions Point Source Loadings (g/d BOD)	9,839	9,839
Critical Conditions Nonpoint Source Loadings (g/d BOD)	27,784,061	32,870,904
Point Source WLA (g/d BOD)	9,839	9,839
Nonpoint Source LA (g/d BOD)	25,004,671	28,527,208
MOS (g/d BOD) [10 percent of TMDL]	2,779,390	3,170,780
Assimilative Capacity (g/d BOD)	27,793,900	32,880,743
Reserve Capacity (g/d BOD)	0	1,172,916
TMDL (g/d BOD)	27,793,900	31,707,827
TMDL (lbs/d BOD)	61,220	69,841

Table 5. Summary of TMDLs, WLAs, LAs, and MOSs for Subsegments 030305, 031001, 030801, 030806, and 030901 (continued).

West Fork/Houston River Subsegments 030901 and 030806	**Summer (Mar-Nov)**	**Winter (Dec-Feb)**
Current Point Source Loadings (g/d BOD)	17,017	17,017
Current Nonpoint Source Loadings (g/d BOD)	7,105,125	6,442,373
Critical Conditions Point Source Loadings (g/d BOD)	17,017	17,017
Critical Conditions Nonpoint Source Loadings (g/d BOD)	5,009,197	3,601,786
Point Source WLA (g/d BOD)	17,017	17,017
Nonpoint Source LA (g/d BOD)	4,506,576	3,239,906
MOS (g/d BOD) [10 percent of TMDL]	502,621	361,880
Assimilative Capacity (g/d BOD)	5,026,214	3,618,803
Reserve Capacity (g/d BOD)	0	0
TMDL (g/d BOD)	5,026,214	3,618,803
TMDL (lbs/d BOD)	11,071	7,971
Bayou D'Inde Subsegment 030901	**Summer (Mar-Nov)**	**Winter (Dec-Feb)**
Current Point Source Loadings (g/d BOD)	2,672,018	2,672,018
Current Nonpoint Source Loadings (g/d BOD)	415,259	433,297
Critical Conditions Point Source Loadings (g/d BOD)	2,672,018	2,672,018
Critical Conditions Nonpoint Source Loadings (g/d BOD)	2,780,377	3,722,394
Point Source WLA (g/d BOD)	2,672,018	2,672,018
Nonpoint Source LA (g/d BOD)	415,259	433,297
MOS (g/d BOD) [10 percent of TMDL]	343,030	345,035
Assimilative Capacity (g/d BOD)	5,452,394	6,394,412
Reserve Capacity (g/d BOD)	2,022,087	2,944,062
TMDL (g/d BOD)	3,430,307	3,450,350
TMDL (lbs/d BOD)	7,556	7,600

MOS Margin of Safety
g gram
kg kilogram
d day
lb pound
BOD biochemical oxygen demand

In subsegments for which the D.O. criteria were violated under season critical conditions, reductions in nonpoint source loadings were made. Percent reductions required in current nonpoint loadings to each subsegment are presented in Table 6. Calibration loadings under season critical conditions were assumed to approximate current loading conditions if season critical conditions occurred. Loading reductions were determined by calculating season critical loadings as percentages of the calibration loadings under season critical conditions.

Under summer critical conditions, the D.O. criteria for all subsegments, except Bayou D'Inde, were attained through reductions in nonpoint source loadings. The D.O. criterion for Bayou D'Inde was attained with no reductions in nonpoint or point sources. Under winter critical conditions, the D.O. criteria in Contraband Bayou and West Fork/Houston River were attainable through reductions in nonpoint source loadings. Reductions in point source loadings to Contraband Bayou were not projected because the current major contributors to the loading are already treating at advanced secondary levels of treatment, and some of these dischargers (Lake Charles Plants B and C) are expected to be removed from Contraband Bayou in the next three to four years. The D.O. criteria for Bayou Choupique and Bayou D'Inde were attained with no reductions in nonpoint or point sources.

Table 6. Percent Reductions in Current Nonpoint Source Loadings Required to Attain D.O. Criteria Under Seasonal Critical Conditions.

Subsegment	**Summer (March - November)**	**Winter (December - February)**
030305 (Contraband Bayou)	71	61
030801& 030806 (West Fork & Houston River)	37	50
031001 (Bayou Choupique)	12	--(1)
030901 (Bayou D'Inde)	--(1)	--(1)

(1) D.O. criterion attained with no reductions in current nonpoint or point sources.

5.0 Sensitivity Analysis

Following calibration, the sensitivity of the model to variations in specific parameters is commonly evaluated through sensitivity analyses. The analyses generally involve adjusting a specific parameter such as a rate or physical dimension and evaluating the effect on a simulated variable. Parameter variations and their effects on model output are evaluated one parameter at a time. The degree to which the parameter is adjusted is normally limited to measured extremes within the study system or values reported in literature. Accepted methods of specifying sensitivity ranges include random number generations such as Monte Carlo, specification of a standard deviation, or by parameter perturbation (adjustment of a parameter by a set percentage of the reference value).

Parameter perturbations of +30 percent and -30 percent were selected for the purpose of analyzing the sensitivity of the calibration model used in this study. In accordance with LDEQ TMDL LTP guidance, selected parameters included carbonaceous decay rate (Kd), nitrogenous decay rate (K_n), benthal oxygen demand or SOD, algal growth, depth, width, and tributary flow. Reaeration rates in the 2002 models are dynamic and are re-computed on an hourly basis, according to the O'Connor-Dobbins Equation. This equation calculates the reaeration rate as a function of stream depth and velocity, which are also dynamic variables in the 2002 models. Therefore, sensitivity to the reaeration rate was not evaluated because the reaeration rate used in the 2002 models is dependent on previously selected sensitivity parameters (depth and velocity). The sensitivity analysis performed on tributary flow provides some index of the model's sensitivity to reaeration. Furthermore, because flow in the RECEIV-II model is advective and dynamic, sensitivity analysis of a dispersion parameter is not applicable and cannot be specified in the model. The sensitivity of the model to the background temperature of the stream was also evaluated in accordance with the LDEQ TMDL LTP guidance. Background temperatures at each node were varied by +2°C and -2°C. Where the resulting background temperature exceeded 32°C, 32°C was used.

The degree of sensitivity was evaluated based on the magnitude of change resulting in simulated versus calibrated D.O. concentrations. The effects on the minimum, maximum, and mean D.O. concentration for all expanded model segments were evaluated. Results of the analysis are presented in Table 7. Detailed analysis calculations are provided in Appendix I. The minimum and mean D.O. concentration were each most sensitive to changes in depth and SOD. The maximum D.O. concentration was most sensitive to flow. The minimum D.O. concentration was least sensitive to K_n; the mean D.O. concentration was least sensitive to background temperature; and the maximum D.O. concentration was least sensitive to depth. The sensitivity of the minimum simulated D.O. concentration to depth and SOD underscore the role of nonpoint source benthal oxygen demand and reaeration on the stream segments modeled in this study.

Table 7. Results of Sensitivity Analysis.

Parameter	Percent Variation in Parameter	Minimum D.O. (mg/L)	Percent Change in Minimum D.O.	Mean D.O. (mg/L)	Percent Change in Mean D.O.	Maximum D.O. (mg/L)	Percent Change in Maximum D.O.
Reference Calibration	--	0.87	0.00	2.03	0.00	4.36	0.00
Kd	-30	0.96	9.33	2.21	9.02	5.11	17.14
	+30	0.77	-12.35	2.06	1.43	5.05	15.63
Kn	-30	0.89	1.80	2.14	5.55	5.08	16.43
	+30	0.89	1.29	2.13	4.89	5.08	16.32
SOD	-30	1.86	112.97	3.35	64.98	5.70	30.58
	+30	0.04	-95.66	1.16	-42.89	4.50	3.09
Algal Growth	-30	1.09	24.21	2.63	29.74	5.43	24.41
	+30	0.40	-54.56	1.95	-4.11	4.96	13.71
Depth	-30	2.31	163.98	3.35	64.84	5.76	31.93
	+30	0.01	-98.60	1.24	-38.90	4.37	0.05
Width	-30	1.70	94.10	2.78	36.84	5.43	24.52
	+30	0.25	-71.84	1.65	-18.62	4.79	9.83
Flow	-30	0.33	-62.27	2.14	5.46	6.01	37.80
	+30	1.10	25.36	2.37	16.91	5.14	17.69
Background Temperature	-30	0.65	-25.55	2.02	-0.61	5.16	18.27
	+30	0.90	3.12	2.19	7.85	5.03	15.33

6.0 Conclusions

Attainment of the D.O. criteria for the subsegments modeled in this study will require focused management of nonpoint sources. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources. For the TMDLs in this report, the nutrient loading required to maintain the DO standards is the nutrient TMDL. LDEQ will work with other agencies such as local Soil and Water Conservation Districts to implement agricultural BMPs in the watershed through 319 cost-share programs. Louisiana's Nonpoint Source Pollution Management Plan outlined the state's approach to nonpoint source pollution control. It describes the types of projects that have been and will be implemented, and it presents information on BMPs that have been determined to be technically feasible and effective in the reduction of pollutant loadings and runoff. In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. LDEQ will continue to monitor receiving waters to determine whether standards and criteria are being attained.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a 5-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the 5-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second 5-year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list. The sampling schedule is shown below.

- 2002 - Red and Sabine River Basins;
- 2003 - Mermentau and Vermilion-Teche River Basins;
- 2004 - Calcasieu and Ouachita River Basins;
- 2005 - Barataria and Terrebonne Basins; and
- 2006 – Mississippi, Pontchartrain, and Pearl River Basins.

The development of this TMDL study was consistent with the State anti-degradation policy (LAC 33:IX.1109.A).

7.0 References

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Appendix A

Detailed TMDL Analyses

Appendix B

Calibration Model Input and Output Data

Appendix C

Calibration Model Development

Appendix D

Projection Model Input and Output Data Sets

Appendix E

Projection Model Development

Appendix F

Survey Plan, Data Measurements, Analysis Results, and Post Survey Report

Appendix G

Historical and Ambient Data

Appendix H

Maps and Diagrams

Appendix I

Sensitivity Analysis

Appendix J

2001 Discharger Inventory

Appendix B1

Calibration Input File for 2002 TMDL Study (2K2Cal.dat)

Appendix B2

Calibration Output File for 2002 TMDL Study (2K2Cal.out)

Appendix D1

Winter Projection Input File (Current Loadings)
for 2002 TMDL Study (2K2CalW.dat)

Appendix D2

Winter Projection Output File (Current Loadings) for 2002 TMDL Study (2K2CalW.out)

Appendix D3

Winter Projection Input File for 2002 TMDL Study (2K2TMDLw.dat)

Appendix D4

Winter Projection Output File for 2002 TMDL Study (2K2TMDLw.out)

Appendix D5

Summer Projection Input File (Current Loadings) for 2002 TMDL Study (2K2CalS.dat)

Appendix D6

Summer Projection Output File (Current Loadings) for 2002 TMDL Study (2K2CalS.out)

Appendix D7

Summer Projection Input File for 2002 TMDL Study (2K2TMDLs.dat)

Appendix D8

Summer Projection Output File for 2002 TMDL Study (2K2TMDLs.out)